

Tuning order in the high temperature superconductors

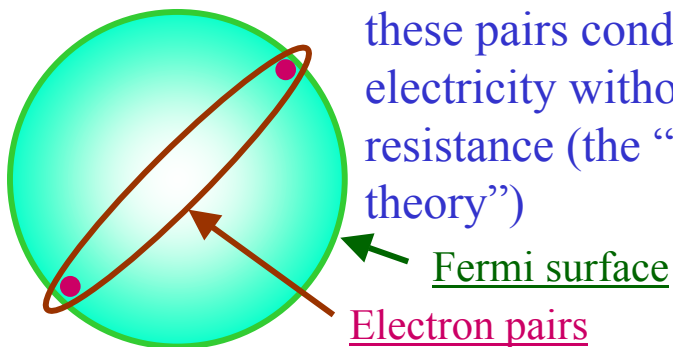
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Conductors of Electricity (before 1986)

- (a) **Metals:** Electrons occupy all quantum states with momenta inside a “Fermi surface”. Scattering of electrons at the Fermi surface leads to resistance and costly heating of electrical wires.
- (b) **Superconductors:** In some materials, electrons at the Fermi surface form pairs below -250°C , and the motion of

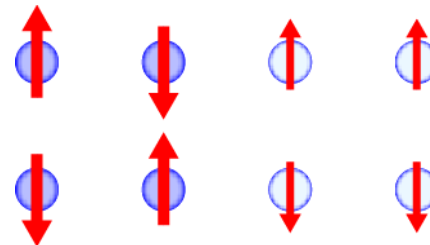


these pairs conducts electricity without resistance (the “BCS theory”)

In large current flow (or in a strong magnetic field), the pairs are broken and the Fermi surface reappears.

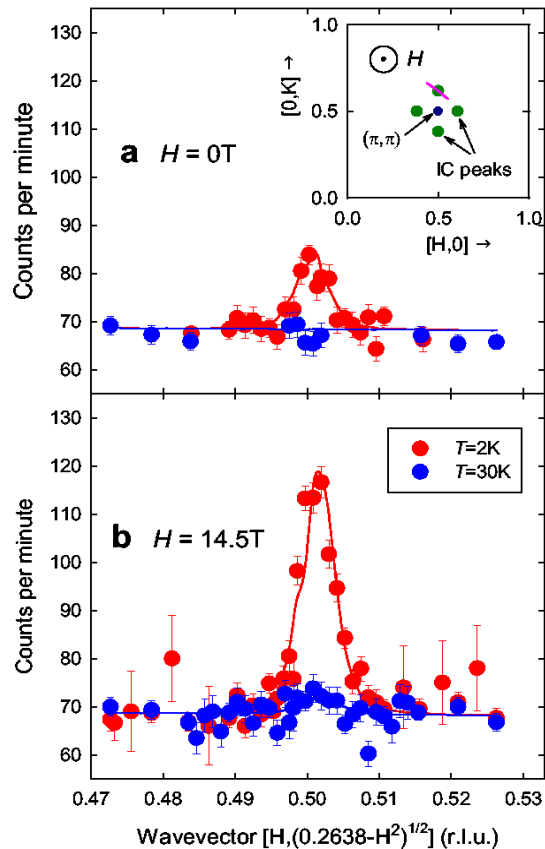
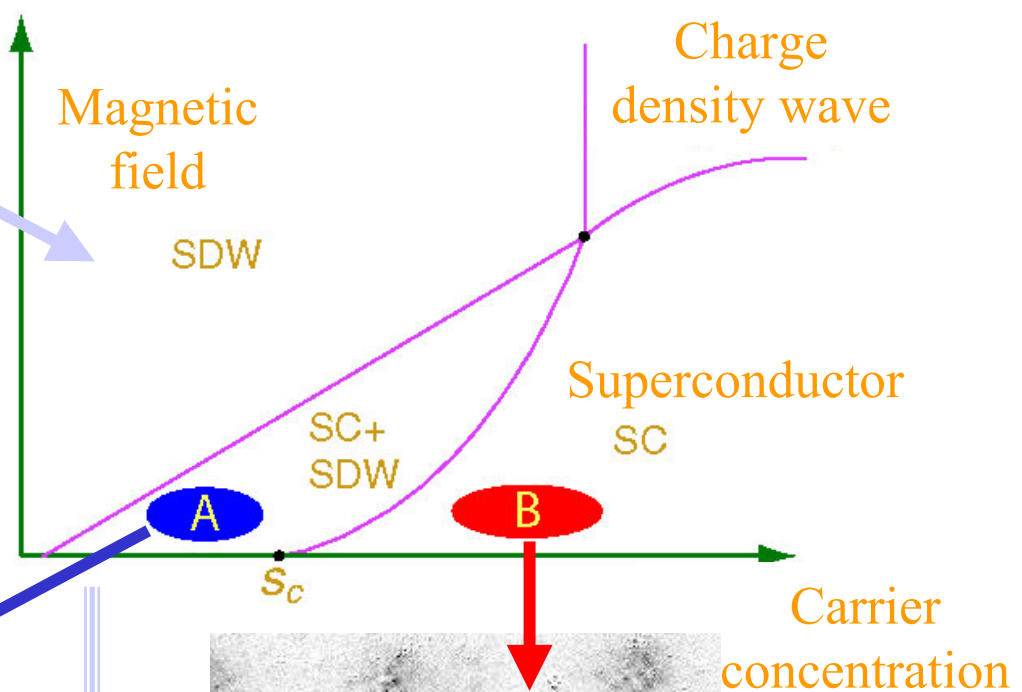
In 1986, a new class of superconductors were found to conduct electricity without resistance at temperatures as high as -170°C . Wires can be cooled to such temperatures easily and cheaply using liquid nitrogen, and new applications involving long-distance power transmission and wireless transmission stations are now appearing.

Our theory predicts that this superconductivity is also due to formation of electron pairs, but *no underlying Fermi surface appears* when the pairs are broken. Instead ***competing “spin and charge density wave orders”*** will be revealed.

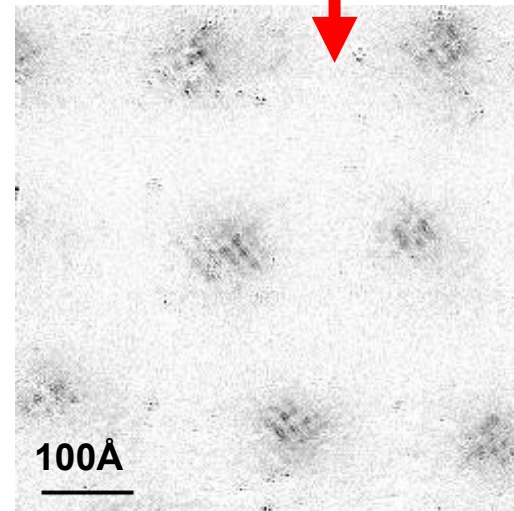


A spin and charge density wave (SDW+CDW)

Predicted phase diagram as a function of applied magnetic field and carrier concentration



A. Scattering measurements reveal enhancement of SDW by a magnetic field H .
B. Lake *et al.* Nature **415**, 299 (2002)



B. CDW revealed in vortices by microscopy measurements.
J. Hoffman *et al.* Science **295**, 466 (2002)